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ENVIRONMENTAL QUALITY
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PREVENTIVE MAINTENANCE PLAN
Title V Sources

Company Name
Site Name
Operating Permit #OP____-__

I. PURPOSE

The purpose of the Preventive Maintenance Plan (PMP) is to supplement engine operating manuals with required maintenance procedures for equipment that could affect emissions. In addition, this plan may be used by those sources without engine operating manuals. Ideally, potential exceedances of emission limitations will be minimized with the implementation of this PMP.

This PMP is also designed to help ensure optimum operation of engines and control equipment, to identify criteria for avoiding situations that could cause control equipment damage, and to identify procedures for finding potential problems in a timely manner. A general maintenance program checklist is attached to show activities that are performed periodically as part of the PMP.

II. ENGINE(S)

Proper engine operation is critical to the performance of control equipment. Emissions are directly influenced by a number of factors that affect combustion temperature and efficiency, including engine timing, type and heat content of fuel, ambient air temperature, relative humidity, fuel temperature, and changes in load.

Engine Operation	Control Technology	Target Pollutants
Rich-burn	NSCR Catalyst (Three-way)	NOx, CO, VOC
Stoichiometric	NSCR Catalyst (Three-way)	NOx, CO, VOC
Lean-burn	Oxidation Catalyst (Two-way)	CO, VOC
	Lean-NOx Catalyst	NOx, CO, VOC
	SCR Catalyst	NOx
	Ceramic Coating	NOx, CO, VOC

Each engine should be scheduled for preventative maintenance every _____ hours of operation; however, this time frame may fluctuate with inclement weather, scheduling logistics, and location constraints. Each engine should be checked on a routine basis for proper operation and misfiring conditions.

III. PERFORMANCE INDICATORS – GENERAL

A. Exhaust Gas Temperature – Temperature is an important factor in determining engine operations and in ensuring appropriate emission controls. Engines are typically equipped with under-temperature and over-temperature shutdown systems. At least annually (or as inclement weather, scheduling logistics, and location constraints allow), the under-temperature and over-temperature shut down systems should be tested to ensure they are working properly. Specific issues pertaining to control equipment temperature considerations are presented in Section IV.

B. Pressure Differential Across Catalyst – Pressure differential can be an important factor in assessing the proper operation of units, especially control units. Specific issues pertaining to control equipment pressure differential considerations are presented in Section IV.

IV. CONTROL EQUIPMENT

A. Non-Selective Catalytic Reduction (NSCR) – An NSCR system reduces NOx, CO, and hydrocarbon (VOC) emissions from a rich-burn engine when the air-to-fuel ratio is near stoichiometric (14.7 to 1). When a rich-burn engine is tuned strictly for performance, oxygen is in the 1% to 3% range. At this AFR, CO and hydrocarbon emissions are low and NOx is high, because the engine is running hot for maximum efficiency. When using an NSCR system, the engine must be operated richer so that an increase in reducing agents (CO and hydrocarbons) occurs. In addition, the NSCR must be operated at a temperature adequate to accomplish NOx reduction, typically at least 750ºF. The catalyst is designed to produce the following reactions:

$$NOx + CO \rightarrow N_2 + CO_2$$

$$NOx + CH_4 \rightarrow N_2 + CO_2 + H_2O$$

$$NOx + H_2 \rightarrow N_2 + H_2O$$

If there is too much oxygen in the exhaust, the preferential reaction in the catalytic converter is the oxidation of CO or hydrocarbon rather than the reduction of NOx. Thus, with NSCR, the oxygen concentration should always be less than 1%, and preferably under 0.5%. The air-to-fuel ratio controller uses an oxygen sensor placed in the exhaust stream near the catalyst inlet as a feedback signal to keep the AFR at the optimum set point. The sensor is particularly sensitive to oxygen concentrations below 1%.

Some conditions that can reduce catalytic activity over time are thermal degradation, poisoning, or masking. Thermal degradation is caused by sintering of the wash coat, which closes the pores, thereby reducing catalyst surface area. Sintering can occur slowly over time, or quickly if the catalyst is operated at a temperature that is too high. Too much sulfur or phosphate in the engine oil or fuel can cause poisoning of the catalyst. Masking occurs when soot is deposited on the catalyst because the engine is burning oil.

Most rich-burn units are fitted with NSCR Control. NSCRs are intrinsically maintenance-free, and periodic inspections are sufficient to help maintain catalytic activity and ensure adequate emission control efficiency. To help ensure each catalyst is operating properly, an annual inspection for physical damage and fouling needs to be conducted. Vacuuming and a low pH washing procedure may be utilized to clean the catalyst. Cleaning procedures and frequencies will depend on each specific situation. When a catalyst is replaced or cleaned, the reference pressure differential needs to be re-established, using a pressure differential gauge or a manometer. After checking the pressure, a portable analyzer (or reference method testing) should be used to confirm that the unit is in compliance with its NO_x and CO limits. Companies should regularly check the inlet to the oxidation catalyst to determine if the appropriate gas temperature and oxygen percentage are present.

1. Oxygen Content of Engine Exhaust Entering Catalyst - As previously discussed, the oxygen content of the engine exhaust gas indicates if the engine is running as rich as is required for proper performance of the NSCR (typically exhaust gas oxygen less than 0.5%). Therefore, oxygen content of gas into the catalyst should be selected as a performance indicator.

   Oxygen content is typically measured using an oxygen sensor that creates an output voltage inversely proportionally to the oxygen content[5]. The output voltage range (typically 0.1 to 0.9 volts in conditions above 650 °F) is site-specific and must be set by using an exhaust gas analyzer to determine the set-point voltage that results in the best emission performance.[5]

   In normal operation, the output voltage will vacillate around the set-point and the AFRC will adjust the step motor to bring the voltage back toward the set-point. When the voltage is above the set-point, the system is richer than desired, and the stepper position is increased to further restrict fuel flow to the carburetor. Conversely, when the sensor voltage is below the set-point, the system is leaner than desired, and the stepper position is decreased to increase fuel flow. In most cases, an alarm will be triggered if the position of a stepper valve is at the minimum travel limit (indicating the engine is too rich and the controller cannot close the valve any further) or maximum travel limit (indicating that the engine is too lean and the controller cannot open the valve any further to enrich the mixture)[5].

2. Exhaust Gas Temperature Entering Catalyst - As mentioned in the overview of NSCR, sintering can occur quickly if the catalyst is operated at a temperature that is too high, and the damage to the catalyst unit would lower or eliminate its effectiveness. On the other hand, a temperature that is too low will interfere with the desired chemical reactions. 40 CFR Part 63, Subpart ZZZZ requires that NSCR-equipped four-stroke rich-burn stationary RICE subject to the formaldehyde emissions standard demonstrate compliance by monitoring the catalyst inlet temperature, and maintaining it within a range of 750^{o}F to $1,250^{o}$F. A requirement to monitor both the catalyst inlet and outlet temperatures would ensure that the preferred temperatures are attained.

   The catalyst outlet temperature range should normally be set as 800^{o}F – 1300^{o}F. Catalyst exhaust temperature should be higher than the catalyst inlet temperature. However, temperature increase across the catalyst is highly site-specific. Some engine/catalyst combinations do not exhibit a significant temperature increase. The catalytic reactions include both exothermic oxidation of CO and hydrocarbons and endothermic NOx reduction. With lower-temperature exhaust or lower hydrocarbon concentrations, a large change in temperature may not occur across the catalyst. In addition, a smaller temperature change will also result if pollutant concentrations in the exhaust are low.

Either the catalyst inlet temperature or the catalyst outlet temperature should be routinely measured. An individual facility may make a site-specific determination of the appropriate exhaust temperature range, as justified by on-site testing and/or manufacturer's recommendation. If feasible, temperature rise across the catalyst can be useful information.

3. Pressure Differential Across Catalyst - Pressure drop across the catalyst should be used as a performance indicator, because a change in pressure drop can indicate that the catalyst is becoming fouled or channeled, and therefore lowering the effectiveness of the unit. Pressure differential is mentioned in 40 CFR Part 63, Subpart ZZZZ. Associated literature suggests that a pressure drop that deviates by more than 2 inches of water from the pressure drop measured during the initial performance test indicates that the catalyst may be damaged or fouled.

   For the purpose of this preventive maintenance plan, a benchmark pressure differential must be established. Ideally, the benchmark pressure differential will be determined immediately after installation of fresh catalyst or a reinstalled catalyst.

B. Oxidation Catalysts - An Oxidation Catalyst system is used to reduce emissions of CO, formaldehyde (CH_2O), and unburned hydrocarbons. The oxidation catalyst system is designed mainly for CO emission reductions from a lean-burn engine, which typically has an air-to-fuel ratio greater than 14.7 to 1. Oxygen contents in the exhaust gas of the lean-burn engine are usually more than 4%, and are typically in a range of 5% to 15%. In order for an oxidation catalyst system to accomplish CO reduction, the exhaust temperature from the lean-burn engine should be at least 450ºF. Generally, the following reactions take place in the oxidation catalyst:

$$CO + \frac{1}{2}O_2 \rightarrow CO_2$$

$$CH_2O + O_2 \rightarrow CO_2 + H_2O$$

$$NOx + H_2 \rightarrow N_2 + H_2O$$

$$C_XH_Y + O_2 \rightarrow CO_2 + H_2O$$

Similar to NSCR catalysts, the performance of the oxidation catalyst is affected by catalytic deactivation, thermal degradation, poisoning, sintering, or masking.

To help ensure each catalyst is operating properly, an annual inspection for physical damage and fouling needs to be conducted. Vacuuming and a low pH washing procedure may be utilized to clean the catalyst. Cleaning procedures and frequencies will depend on each specific situation.

In addition, the catalysts are designed to perform with a minimum flue gas temperature of 450°F and a minimum oxygen content of 4.0%. Companies should regularly check the inlet to the oxidation catalyst to determine if the appropriate gas temperature and oxygen percentage are present.

1. **<u>Exhaust Gas Temperature Entering Catalyst</u> - As previously mentioned, oxidation catalyst requires minimum inlet temperature of 450ºF to reduce formaldehyde emissions. Therefore, the typical minimum inlet temperature for the oxidation catalyst should be at least 450ºF. 90% of CO reduction can be achieved at 450ºF and 60% to 80% of CH_2O reduction can be achieved at 550 ºF according to literature. 1,350ºF is a typical temperature used as an upper limit to assure both proper oxidation of unburned hydrocarbons and protection of the oxidation catalyst.**

   Monitoring exhaust temperature at either the inlet or outlet of the catalytic unit can ensure proper performance of the catalyst. The temperature rise across oxidation catalyst could be set as an indication of catalyst performance. However, the temperature rise is significantly affected by ambient conditions and some oxidation catalysts show small temperature rise. Therefore, the minimum requirement is to monitor either the catalyst inlet, with a range of 450°F to 1,350°F, or outlet temperature, with a range of 500°F to 1,350°F. An individual facility may make a site-specific determination of the appropriate exhaust temperature range, as justified by on-site testing and/or manufacturer's recommendation.

2. **<u>Pressure Differential Across Catalyst</u> - As with NSCR, the pressure differential across the catalyst should be used as a performance indicator. The rationale for this performance indicator is the same as that for the NSCR catalyst. If the pressure differential across the catalyst deviates by more than 2 inches of water from the pressure drop across the catalyst measured during the initial performance test, the catalyst may be damaged, fouled, or channeled.**

   For the purpose of this PMP, a benchmark pressure differential must be established. For fresh catalyst or reinstalled catalyst, a pressure differential reading is required immediately after installation, and should be used as the benchmark. The PMP should set an acceptable range for the pressure differential across the catalyst as a deviation of less than 2 inches of water from the benchmark.

   When a catalyst is replaced or cleaned, the bench mark pressure differential needs to be re-established, using a pressure differential gauge or a manometer. After checking the pressure, a portable analyzer (or reference method testing) should be used to confirm that the unit is in compliance with its NO_x and CO limits.

C. <u>Air-Fuel Ratio (AFR) Controllers</u> - An AFR controller is typically used to control the oxygen content of the air-fuel mixture within the combustion chamber. AFR controllers can have a significant impact on NOx and CO emissions; therefore, proper operation/setting is very important to achieving the NOx and CO emission regulations regularly. The AFR controller should be routinely checked, along with the percent oxygen level, to ensure it is operating properly. Corrective action to finding emission problems may include adjusting the engine timing to a different setting, at which the AFR controller can adequately adjust the AFR over the expected range of fuel heat content and loading. Should a company find that its AFR is routinely needing to be manually adjusted for ambient conditions, the company should consider the purchase, installation, operation of an AFR built with more modern technology.